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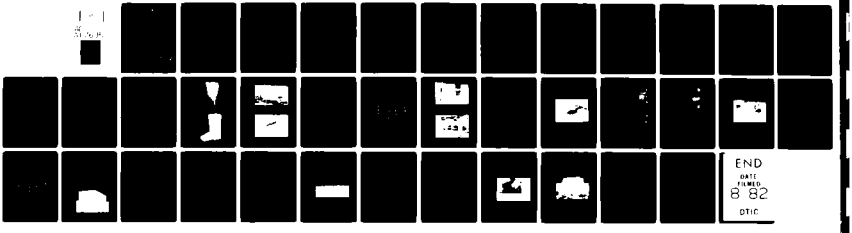

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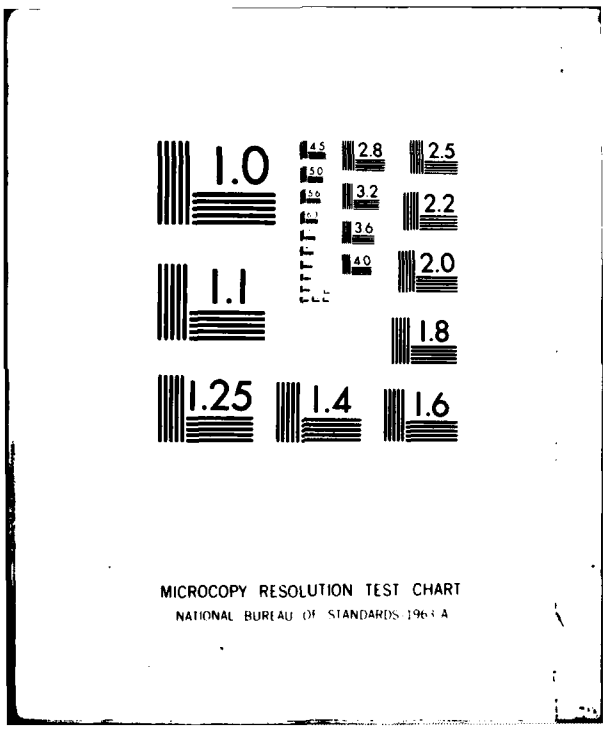
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EXPLOSIVES INSTRUMENTATION GROUP TRIAL 6/77-PROPELLANT FIRE TRIALS (SERIES TWO)

I.J. Walters and A.V. Pleckauskas

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ABSTRACT

A series of fire trials were carried out for the Operational Safety Committee to determine the effect of packaging and containerization on the hazard categorization of AR5401, and by similarity AR2201, when those propellants are subjected to a fuel fire as may be experienced when transported on board ship.

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16. *ABSTRACT (If this is secret, the announcement of this report will be similarly classified):*

A series of fire trials were carried out for the Operational Safety Committee to determine the effect of packaging and containerization on the hazard categorization of AR5401, and by similarity AR2201, when those propellants are subjected to a fuel fire as may be experienced when transported on board ship.

CONTENTS

EXPLOSIVES INSTRUMENTATION GROUP TRIAL 6/77-PROPELLANT FIRE TRIALS

(SERIES TWO)

1. INTRODUCTION

The Operational Safety Committee decided in May 1975 to conduct a series of propellant fire trials to assist in a review of the categorization of some single base propellants when packed and stored under conditions encountered in the local storage and transport facilities. A working party was established to co-ordinate the management of the trials and the Materials Research Laboratories were tasked with the responsibilities for the planning and execution of the trials.

The outcome of this series led to recommendations concerning the recategorization of NH012, FNH016 and AR2201, and the desirability of conducting further trials to assess the effect on categorization when propellants are contained in other packages and when confined within shipping containers. These points are important considerations in relation to any overseas sales since the cost penalty of providing a higher than necessary standard of packaging could mean the difference between a successful or unsuccessful tender.

Consequently a second series of trials was planned with the following objectives:

(a) To determine the behaviour of single base propellants, particularly AR2201, when packed in various boxes, drums and cans including the M2 steel propellant can, and on the basis of these tests to propose one type of cost effective package for use with overseas and commercial sales of these materials;

(b) To determine the categorization of the propellant in the various types of packages; and

(c) To determine the effect of containerization when filling an ISO shipping container with AR2201.

Four trials were conducted in this series which are described in this Technical Note.

2. TRIAL 6A/77

2.1 Trial Description

This trial was conducted at the Ravenhall Test Area in December 1977. Four M2 cans of AR2201 were initiated individually by a match-head inserted into a bag of black powder. The igniters were remotely activated by a 270 volt electric firing unit. The first can was fired with the lid off while the remaining three had their lids clamped on. All cans were standing with the lid-end upwards when initiated. Air blast measuring instrumentation was used to determine the effective explosive yield in the event that the propellant detonated. Also, colour cine records were taken of each test and meteorological conditions were recorded.

2.2 Trial Results

The first can (without a lid) burnt vigorously for approximately 45 s. Fig. 1a shows the can after burning. The remaining three cans also burnt vigorously, consuming the propellant within 30 s; in each case the lids of the cans were blown off, as shown in Fig. 1b.

3. TRIAL 6B/77

3.1 Trial Description

This trial was conducted at the Ravenhall Test Area in June 1978. One can containing propellant AR2201 and two cans containing propellant AR5401 were each in turn suspended over a liquid fuel fire (see Fig. 2a). Each can contained 55 kg of propellant. AR5401 was tested to determine its similarity to AR2201 with a view to using it as a substitute for AR2201 in a later trial (6D/77), as sufficient quantities of the substitute were more readily available and cheaper.

The fire hearth, in which the fuel was contained, was prepared in the ground and measured 1.5 m(l) x 1.5 m(w) x 0.2 m(d). The hearth was lined with plastic sheeting to prevent seepage after fueling.

The liquid fuel fire consisted of 200 *l* of kerosene in the first test and 100 *l* in each subsequent test. In order to ensure rapid ignition of

the kerosene, 20 *l* of petrol was added and initiated by squirt igniters remotely activated by a firing unit from the instrumentation control station. In the event of the propellant not burning, a back-up firing system was placed inside the cans. The back-up system consisted of a hot wire igniter which was connected to a separate firing unit via flame resistant wires.

Air-blast measurement instrumentation was provided to determine the effective explosive yield in the event that the propellant detonated. This data was recorded using a Brüel & Kjaer 3 mm condenser microphone and a Teac-410 instrumentation magnetic tape recorder.

Temperature measurements were performed using fibreglass insulated chromel-alumel thermocouples placed at the base and centre of each can. A thermocouple was also placed in the fire to monitor the fuel fire temperature.

Colour cine and still photography of each event was taken. The cine camera used was a 16 mm Bolex filming at a rate of 24 frames/s.

3.2 Trial Results

Temperature/time records for the measurement point at the base of each can are shown in Fig. 3. The temperature/time records for the point at the centre of each can are not shown as a poor signal to noise ratio persisted for each event. The approximate cook-off and propellant burn times are given in Table 1; these times were determined from the temperature/time records. The cook-off times are the estimated times from when the fire records first indicated a temperature increase and when the cans ignited. Ignition of the cans was assumed to be at the points on the records near the ignition temperature of the propellants which are 175°C and 165°C for AR5401 and AR2201 respectively [1,2]. After propellant ignition, the temperature records are, generally, no longer smooth as may be expected.

Air-blast pressure instrumentation indicated that no high order reaction occurred in any of the three events. Meteorological observations of the wind strength and direction was light and variable respectively.

An example of the typical damage to the M2 cans during this trial is shown in Fig. 2b. Comparing the photographs of the cans damaged previously (trial 6A/77 Fig. 1b) to that of Fig. 2b, an obvious difference in reaction did occur when the propellant was ignited over a fuel fire; the reaction was more severe for the fuel fire test.

Propellants AR2201 and AR5401 appeared to have similar burning characteristics over a liquid fuel fire.

4. TRIAL 6C/77

4.1 Trial Description

This trial was conducted at Army, P & EE, Graytown, in July 1979. The trial was designed to determine the explosive and/or fire hazard of AR2201 and AR5401 propellant when contained in steel cans and banded into pallets of 13 cans (see Fig. 4).

A two-tiered pallet containing cans (see Fig. 5) of AR2201 on the lower level and inert fill on the upper level, were burned over a liquid fuel fire. The test was repeated using AR5401 to detect any differences in reactions of the two propellants. The inert pallet, containing cans of sand, was placed on top of the pallet of propellant cans in order to simulate the increased containment caused by this stacking arrangement. The net weight of propellant per pallet was approximately 700 kg.

The pallets were positioned on a steel stand above the fire hearth (see Fig. 5a), which was filled with 400 *l* of kerosene and 40 *l* of petrol. Two hearths, 30 m apart, were used so that there would be minimal delay between tests. This arrangement also obviated the hazards of setting up the next test when unburnt propellant and/or hot material was laying around.

Each hearth had water pumped into it as required to ensure the correct distance between the surface of the fuel and the pallet. The hearths were 2.5 m(l) x 2.5 m(w) x 0.33 m(d) with smooth sand bases and lined with plastic sheets. The earth was banked 1 m high on 3 sides to protect the fuel fire from wind. The fuel was estimated to burn for 10 min.

The fire was to be simply initiated by two squirt igniters via a 270 V firing unit but strong winds prevented reliable ignition. Instead, mortar charge bags of propellant were needed and these were initiated by the squirt igniters.

4.2 Trial Instrumentation

4.2.1 Temperature Measurement

Temperature measurements were performed using six fibreglass insulated chromel-alumel thermocouples; five were positioned in cans (see Fig. 4) and one just above the fuel surface.

The thermocouples' reference junctions were placed in a buried ice-point reference and the outputs were connected to differential amplifiers buried near the hearth (see Fig. 5b). The amplified signals were multiplexed and transmitted to the instrumentation van where they were recorded on a Teac-410 instrumentation magnetic tape recorder.

4.2.2 Air-blast Measurement

To measure the over-pressure generated by a possible detonation of the propellant, two Kistler 701A pressure transducers, and a Brüel and Kjaer 3 mm condenser microphone, were used. Fig. 6 shows the instrumentation layout. The Kistler gauges, mounted in the ground in concrete blocks (see Fig. 7), were coupled to a Biomation 805A waveform recorder via Kistler charge amplifiers. The output from the microphone was recorded on a Kistler peak-meter.

4.2.3 Meteorology

Wind speed and direction, ambient temperature and pressure, and relative humidity were recorded during the burn.

4.2.4 Photography

Colour high speed cine films were taken to record the burning of the propellant using a $\frac{1}{2}$ frame Hycam camera filming at a rate of 2000 frames/s. A 19 mm Sony U-Matic video cassette recorder (VCR) and camera were used to view the hearth from a tower 100 m from ground-zero (GZ). Normal cine and still photography was taken as required throughout the trial.

4.3 Trial Results

Similar cook-off times were recorded for both the AR2201 and AR5401 propellants as shown in Table 2. Due to initiation problems, fuel ignition was delayed for the first test during which time petrol was lost by evaporation; this would have the effect of increasing the time for the flame to spread after the fuel was subsequently ignited using the mortar bags. The temperature/time records show a slower rate of rise of fire temperature for this test (Fig. 8a).

The severity of the reaction for both propellants was similar in that when a can (or cans) ignited, rapid periodic burning was observed. Fig. 9 shows the fire hearth after burning.

The fuel fire functioned properly and gave more than sufficient burning time for the tests thus verifying the accuracy of the scaled tests from previous trials.

Meteorological data are given in Table 3.

5. TRIAL 6D/77

5.1 *Trial Description*

This trial was conducted at Army, P & EE, Graytown, in September 1980. The trial was designed to determine the explosive and/or fire hazard of small arms propellant when they are contained in M2 steel cans stacked into an ISO shipping container which is placed over a liquid fuel fire.

The ISO shipping container, comprising 9 tonnes of AR5401 propellant contained by twelve pallets of cans, was transported by road from the Explosives Factory, Maribyrnong, to P & EE, Graytown. The container was internally braced with wooden framing to prevent shifting of the load during transportation. Fig. 10 shows pallet location and identification while Fig. 11 shows the can configuration of each of the pallets.

The external heat source for this test was provided by a liquid fuel fire of 6000 *l* of kerosene and 400 *l* of petrol to ignite the kerosene. The hearth, in which the fuel was contained, measured 7.35 m(l) x 3.5 m(w) x 0.36 m (d). The surfaces of the hearth were lined with plastic sheet. The container was mounted on three 'I' section steel beams above the hearth (see Figs. 12a and 12b).

The fuel was ignited by four squirt igniters which, as a result of the previous trial, were modified to give a longer duration flame. The igniters were positioned midway along each side of the hearth and just above the fuel surface. Initiation of the igniters was by a remote electric firing unit which also sent a timing pulse to all recording instrumentation to act as a time-zero (TZ) reference.

In the event of the propellant not burning, a back-up firing system was placed inside the container to initiate the propellant if necessary. The system consisted of a hot wire igniter placed inside a can of propellant and connected to a separate firing unit via a flame resistant wire. Three separate cans contained this back-up system.

5.2 *Trial Instrumentation*

5.2.1 *Temperature Measurement*

Temperature measurements were performed using eleven fiberglass insulated chromel-alumel thermocouples; five were situated in cans (see Fig. 13), three were in the fuel fire (see Fig. 14) and three were attached to the ISO container (see Fig. 15). Table 4 shows thermocouple identification, location and maximum temperature range.

The thermocouples were used with an ice-point reference and differential amplifiers. These were buried near ground zero (see Fig. 5b) to protect the instrumentation from radiated heat. The signal outputs from the differential amplifiers were multiplexed and transmitted to a Teac-410 instrumentation magnetic tape recorder situated in the instrumentation van.

5.2.2 Air-blast Measurement

To measure over-pressure generated by a possible detonation of the propellant, pressure transducers and one microphone were positioned at the measurement points shown in Fig. 14. Two Kistler 701A pressure transducers were set up to measure pressures from ambient up to 700 kPa and 300 kPa at positions C and D respectively (see Fig. 14). The gauges were mounted on two separate baffle plates (see Fig. 16). A baffle plate is a disc bevelled at the edge to produce a laminar flow across the face of the transducer. A Kistler 202 gauge (position E, Fig. 14) was set up to measure pressures from ambient up to 55 kPa. This gauge was mounted in a concrete block flush with the ground (see Fig. 7). At point F, a Brüel and Kjaer 3 mm condenser microphone (type 4138), mounted on a tripod 500 m from the hearth, was set up to measure pressures from ambient up to 4 kPa. The charge amplifiers used with the pressure transducers were housed in aluminium boxes to protect them from flying debris and adverse weather conditions. The amplified output signals were recorded either by Biomation 805 waveform recorders or a Teac-410 instrumentation tape recorder.

5.2.3 Meteorology

Wind speed and direction, ambient temperature and pressure, and relative humidity were recorded during the burn.

5.2.4 Photography

Two Bolex 16 mm cine cameras, filming at a rate of 24 frames/s, were used to view the container from a distance of 300 m (see Fig. 14). The cameras were housed in armoured camera boxes. One camera was triggered before TZ and the second camera commenced to film before expiry of the first. A flashbulb in the near field of the two cameras was used to indicate when the second camera started. This procedure permitted increased recording time of the event.

A 19 mm Sony U-Matic VCR and camera was used to view the container from a different angle. The camera was mounted in an armoured camera box and located 100 m from GZ (see Fig. 14).

Still colour photography of the event and trial site was taken with 35 mm slide and 58 mm square format.

5.3 *Trial Results*

The temperature range of the thermocouples in the fire extended from ambient up to 800°C. The ranges of the thermocouples fixed to the container and propellant cans were either ambient up to 200°C or ambient up to 800°C. Temperature/time records are shown in Figs. 17a and 17b. The times for the fuel fire to reach 550°c [3] are given in Table 5 while the times for the cans to reach 175°C (ignition temperature of AR5401) are given in Table 6.

The magnitude of the pressure wave from the burning propellant was insignificant as no detonation occurred. The meteorological data is tabulated in Table 7.

The cine and VCR records show that the propellant was burning no earlier than 1 min 5 s after TZ. At this time, traces of white smoke were observed streaming from the container. Vigorous burning occurred at 3 min (see Fig. 18) reaching a peak at 3 min 25 s when the doors were thrust open displacing the container longitudinally by about 3 m. The fireball produced by this vigorous burning extended to a radius of about 30 m. Cans were propelled from the opening for a distance of about 80 m (see Fig. 19). The propellant was totally consumed within 4 min.

6. REFERENCES

1. MRL Safety Certificate No. 22.

2. MRL Safety Certificate No. 37.

3. Specification for the Establishment of a Standard Fuel Fire; Ordnance Board (UK) Proceedings No. 41089 Appendix D.

7. ACKNOWLEDGEMENT

The authors wish to acknowledge the work of the other members of the Explosives Instrumentation Group involved in this trial, the Explosives Devices Group for their work in preparing the fuel initiators, and the assistance of the Quality Assurance Division (Army) in conducting this trial.

TABLE 1

COOK-OFF AND BURN TIMES (TRIAL 6B/77)

PROPELLANT	COOK-OFF TIME (s)	PROPELLANT BURN TIME (s)
AR2201	24	5
AR5401	22	7
AR5401	18	3

TABLE 2

COOK-OFF TIMES (TRIAL 6C/77)

THERMOCOUPLE NO	COOK-OFF TIMES (s)	
	AR5401	AR2201
1	13	15
2	22	16
3	19	19
4	N.R	N.R
5	14	13
6	29	14
7	29	15

N.R. - No Record

TABLE 3

METEOROLOGICAL DATA (TRIAL 6C/77)

EVENT	DATE	TIME OF DAY	AIR PRESSURE (mb)	AIR TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	WIND	
						SPEED (m/s)	DIRECTION
1	24/7/79	1345	1006	11	44	3	S/SSE
2	25/7/79	1142	1008	15	52	2	ENE/ESE

TABLE 4

THERMOCOUPLE IDENTIFICATION (TRIAL 6D/77)

THERMOCOUPLE NUMBER	LOCATION	RANGE (ambient to) (°C)
1	Fire (rear right)	0-800
2	Fire (middle)	0-800
3	Fire (left front)	0-800
4	Inside container (left side)	0-200
5	Inside container (right side)	0-800
6	Inside container (floor)	0-200
7	Pallet/can E/7	0-800
8	Pallet/can E/9	0-200
9	Pallet/can F/7	0-200
10	Pallet/can M/9	0-800
11	Pallet/can N/7	0-200

T A B L E 5

TIME FOR FIRE TEMPERATURE TO REACH 550°C (TRIAL 6D/77)

THERMOCOUPLE*	1	2	3
Time to 550°C (S)	19.5	16.0	40.5

*See Figure 14. For thermocouple locations.

T A B L E 6

COOK-OFF TIMES OF M2 CANS OF PROPELLANT (TRIAL 6D/77)

Thermocouple*	7	8	9	10	11
Time to 175°C (S)	33.0	31.0	31.5	32.5	32.5

*See Figure 13

T A B L E 7

METEOROLOGICAL DATA (TRIAL 6D/77)

DATE	TIME OF DAY	AIR PRESSURE (mb)	AIR TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	WIND	
					SPEED (m/s)	DIRECTION
17/9/80	1600	986	22	50	5-7	NNW

FIG. 1a - Photograph of the M2 can (without lid) after burning (Trial 6A/77).

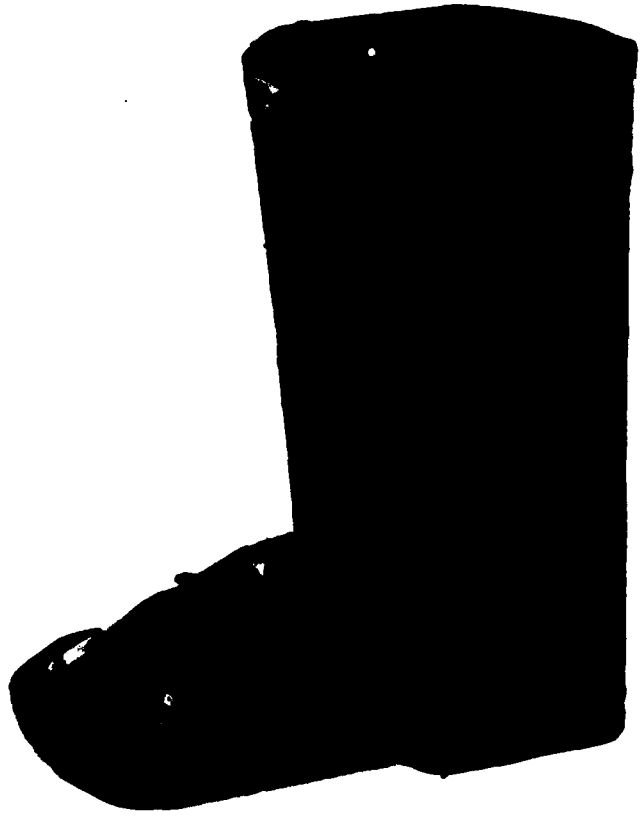


FIG. 1b - Photograph of the M2 can (with lid) after burning (Trial 6A/77).

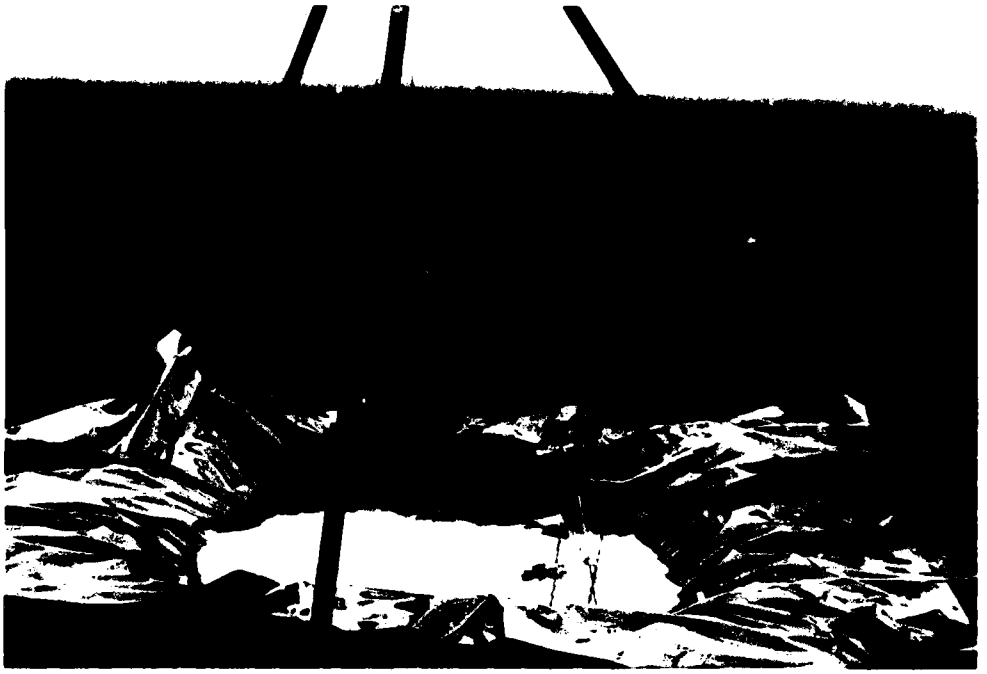


FIG. 2a - Photograph of the M2 can suspended over the liquid fuel fire hearth (Trial 6B/77).

FIG. 2b - Photograph of the damage sustained by a M2 can after burning (Trial 6B/77).

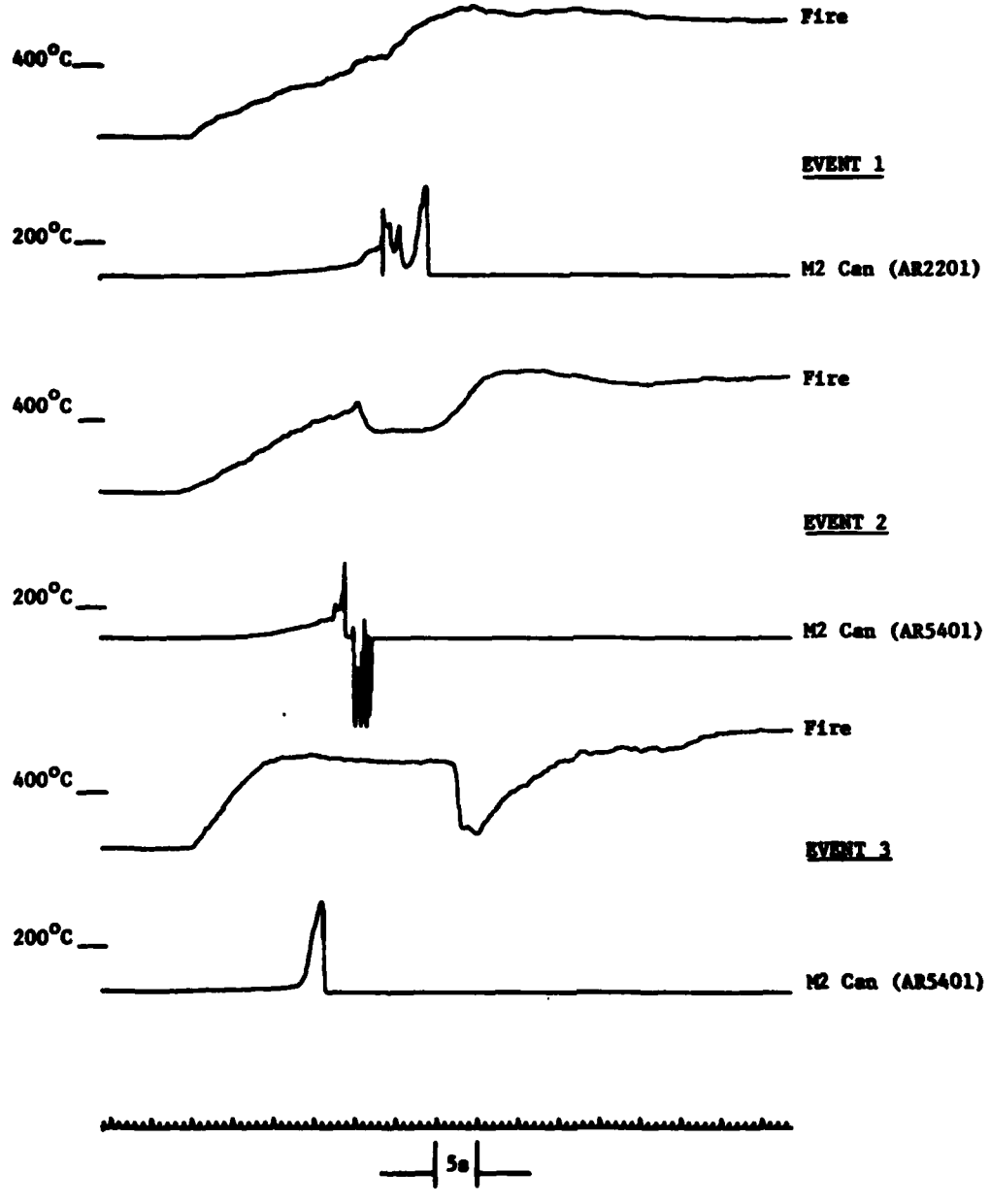


FIG. 3 - Temperature/time records for Trial 6B/77.

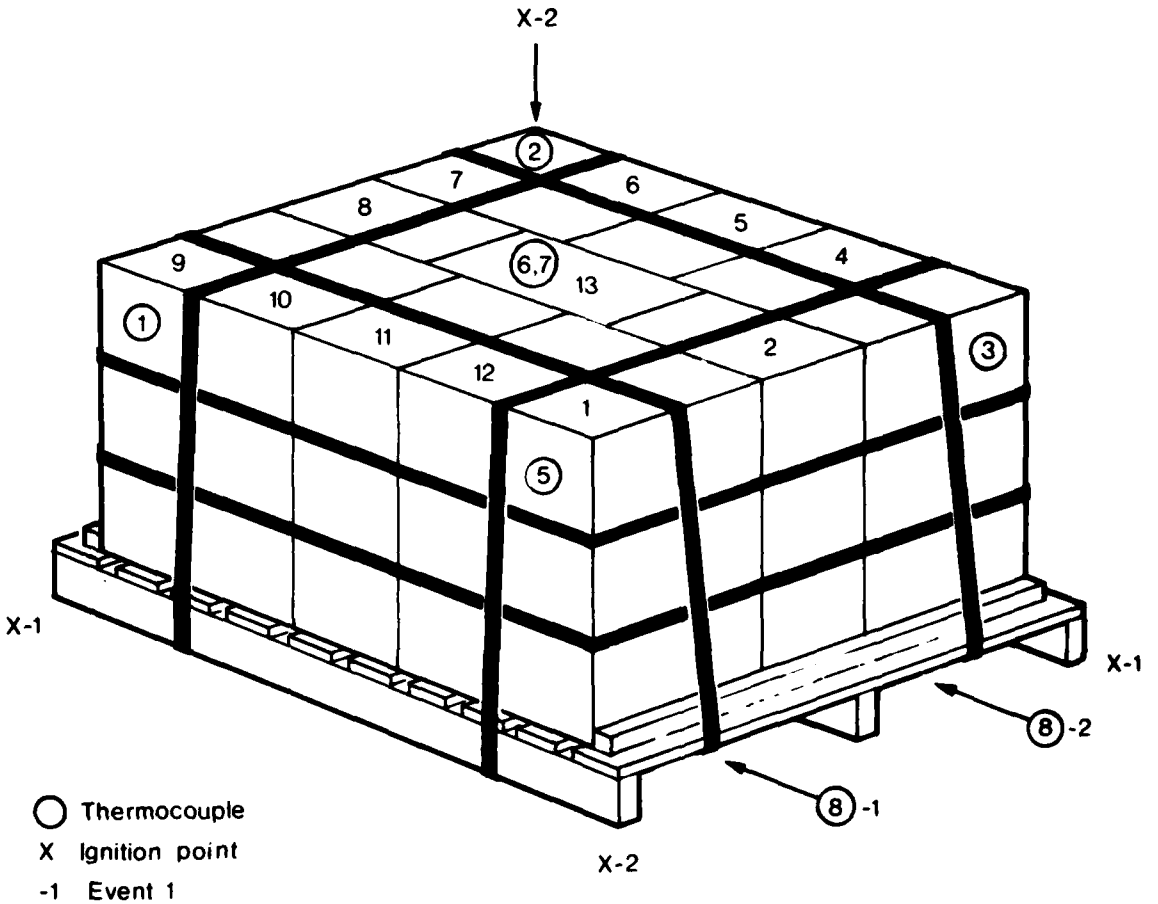


FIG. 4 - Schematic of pallet stack, instrumentation layout and fuel fire ignition points. (Trial 6C/77).

FIG. 5a - Photograph of two tiered pallet stack (Trial 6C/77).

FIG. 5b - Photograph of instrumentation bunker near ground zero (Trial 6C/77).

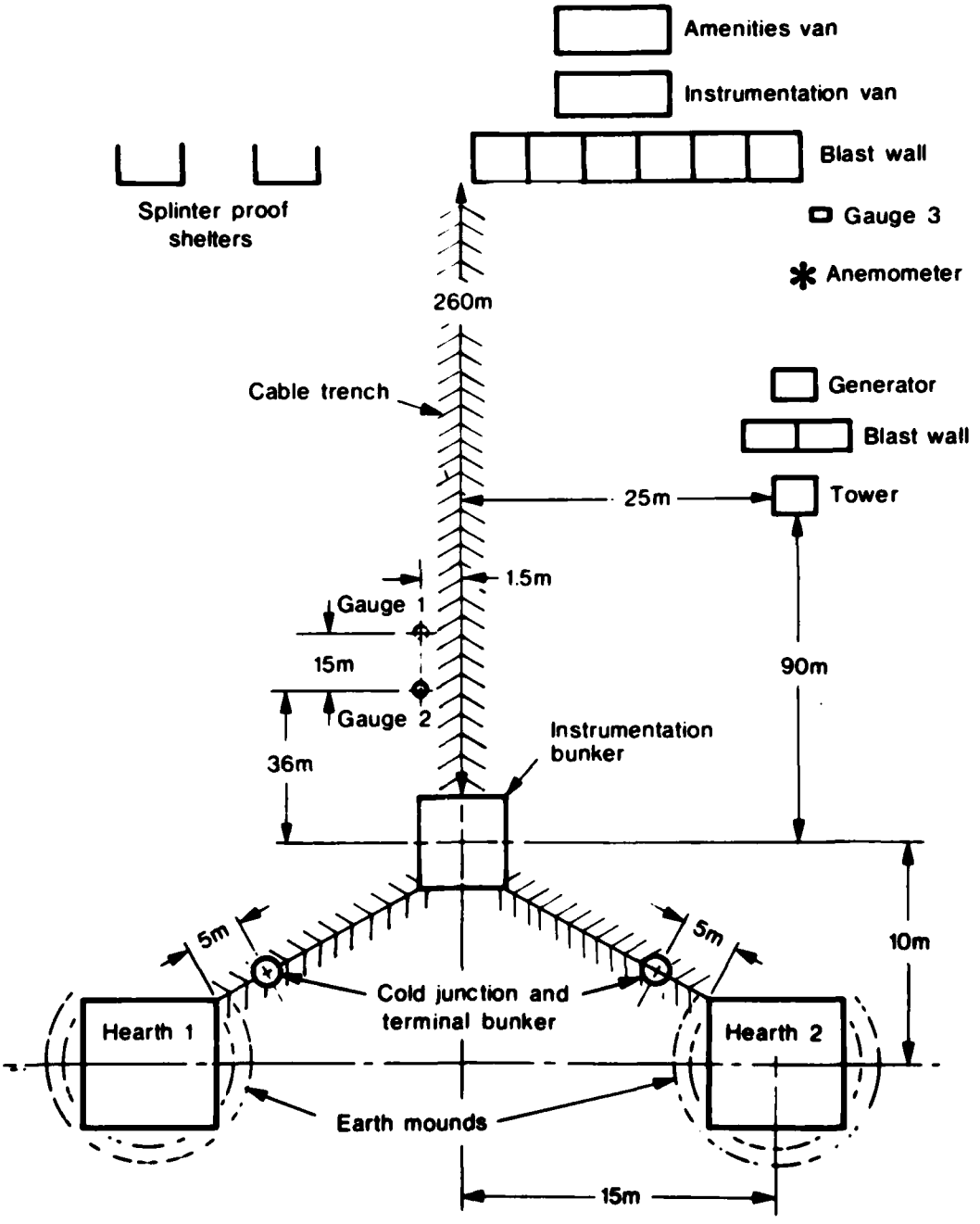


FIG. 6 - Instrumentation layout (Trial 6C/77).

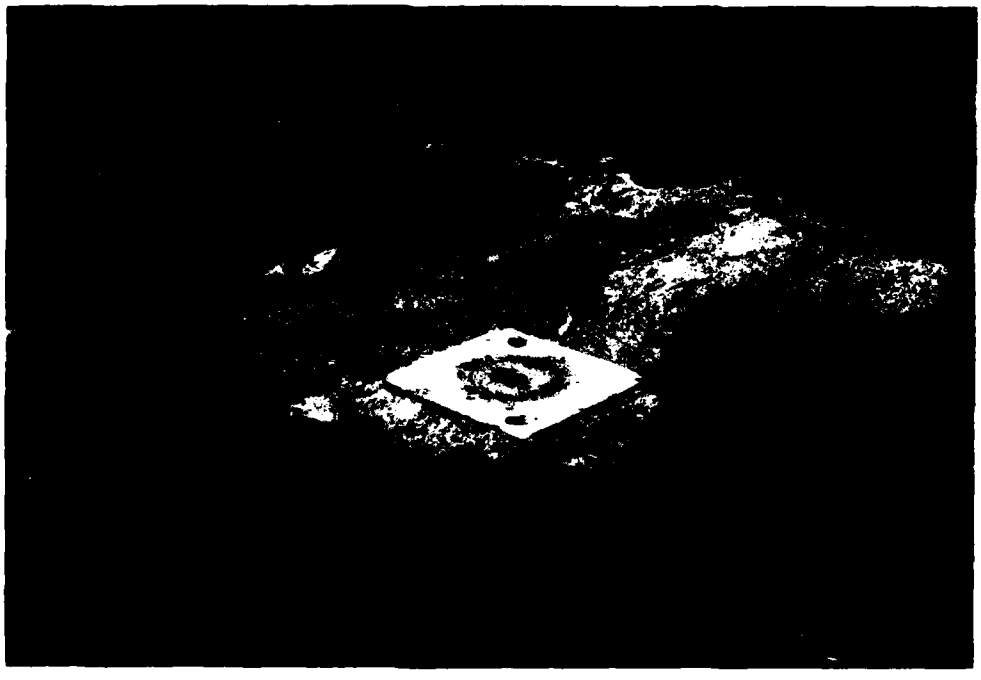


FIG. 7 - Photograph of a Kistler 202 gauge set in a concrete block.

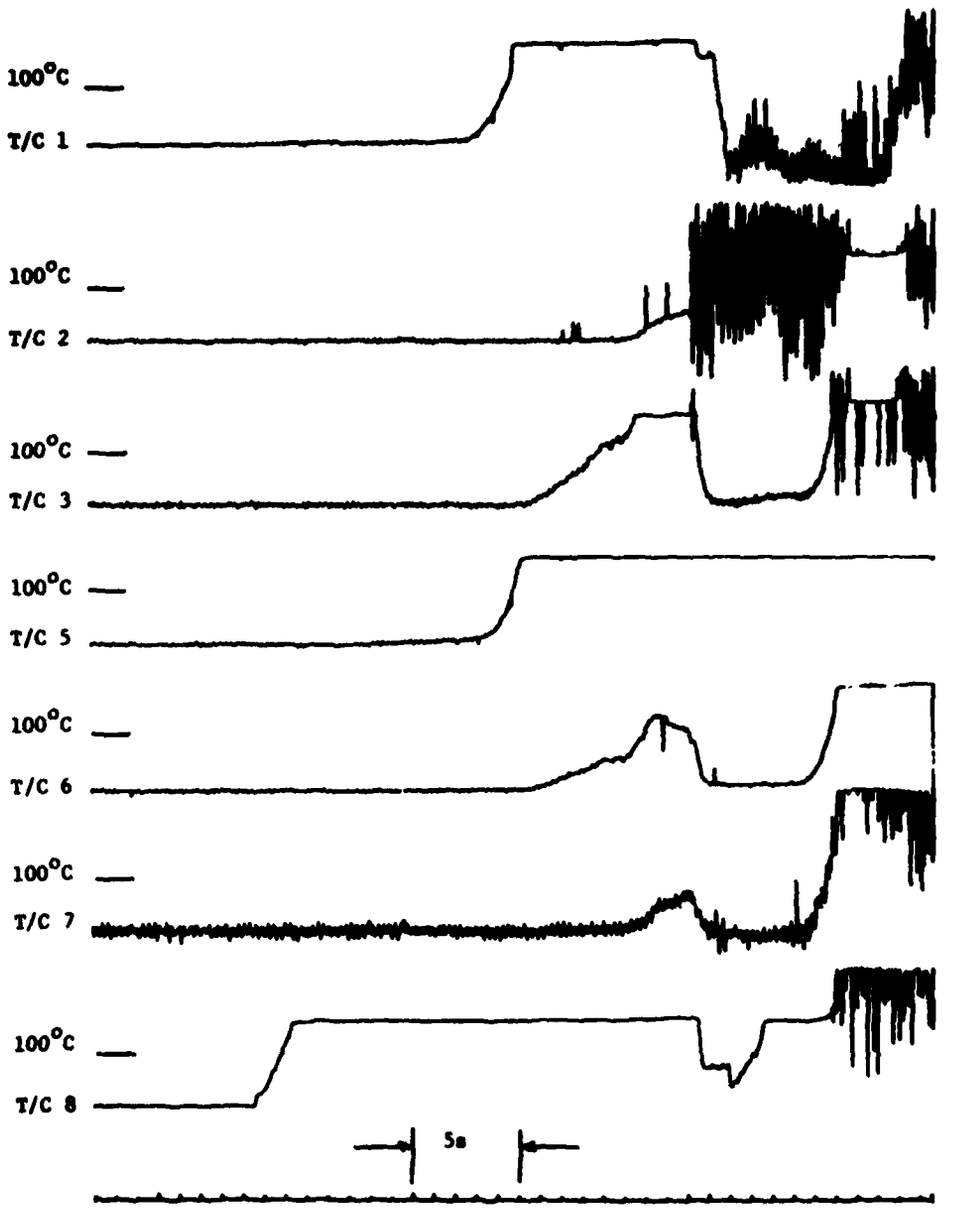


FIG. 8a - Temperature/time records for AR2201 propellant (Trial 6C/77).

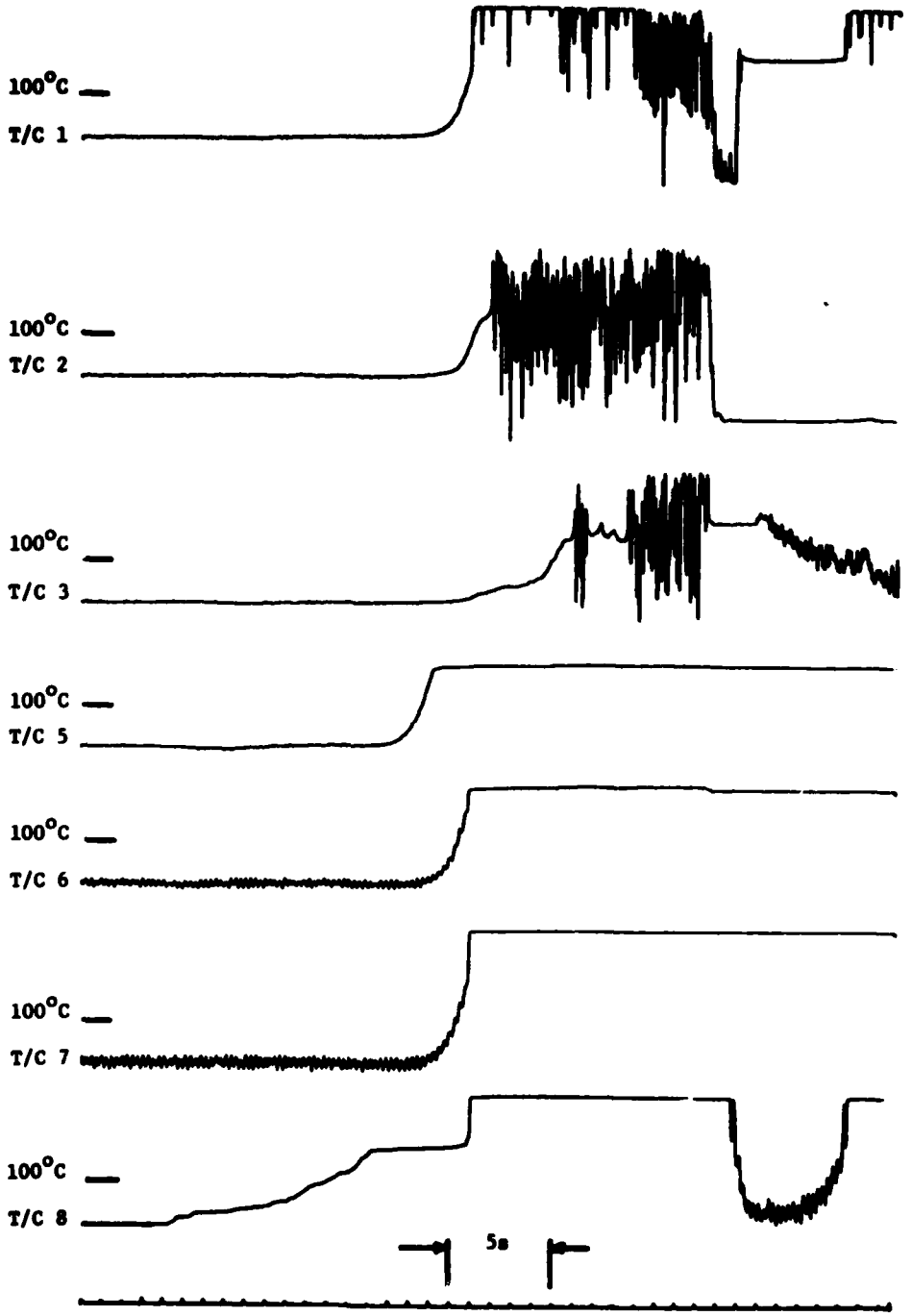
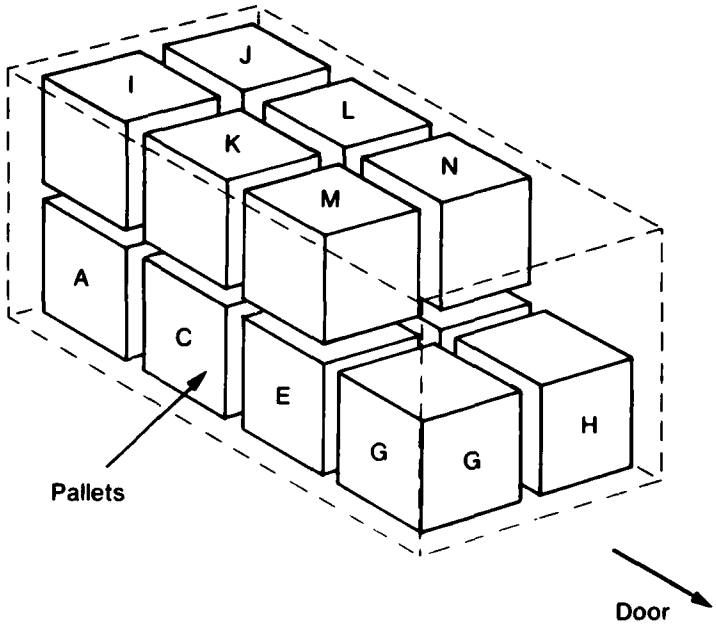


FIG. 8b - Temperature/time records for AR5401 propellant (Trial 6C/77).

FIG. 9 - Photograph of fire hearth after burning (Trial 6C/77).



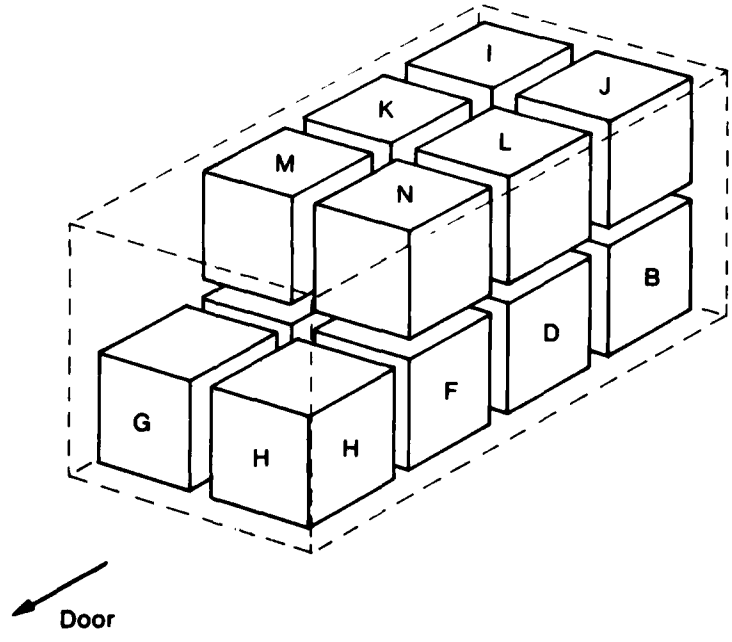


FIG. 10 - Pallet location and identification (Trial 6D/77).

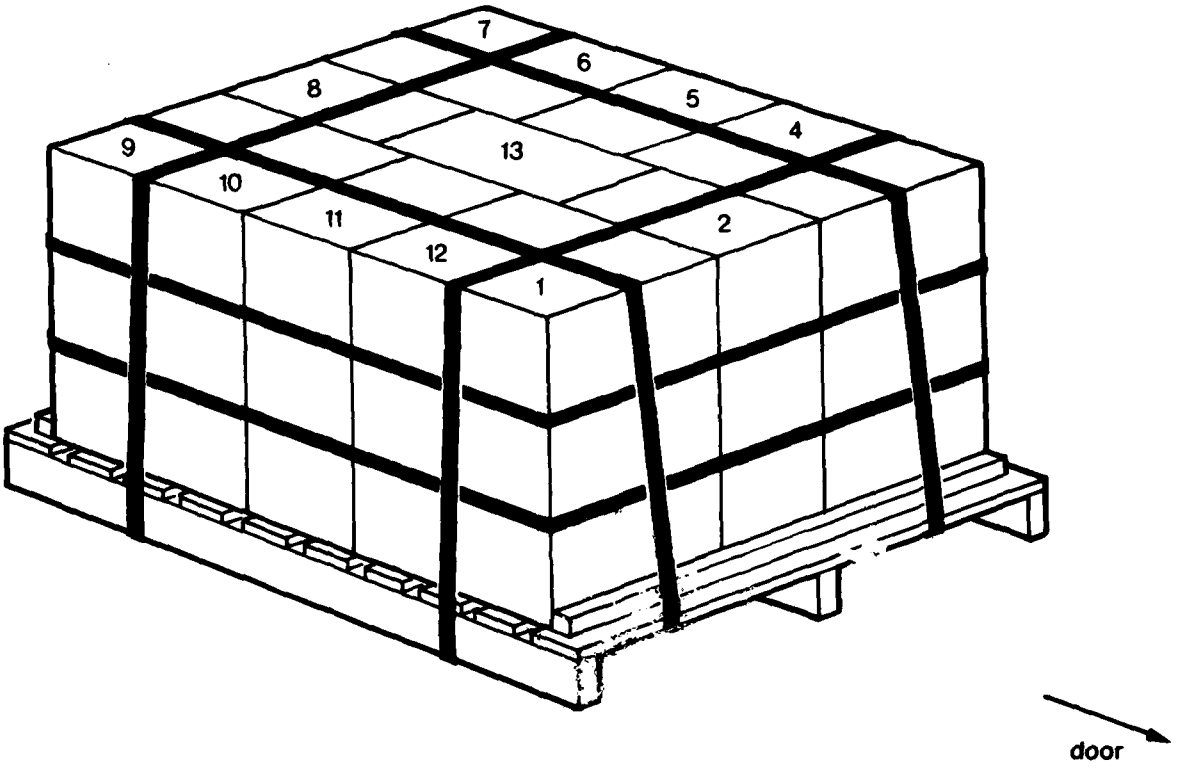


FIG. 11 - Can configuration on each pallet (Trial 6D/77).

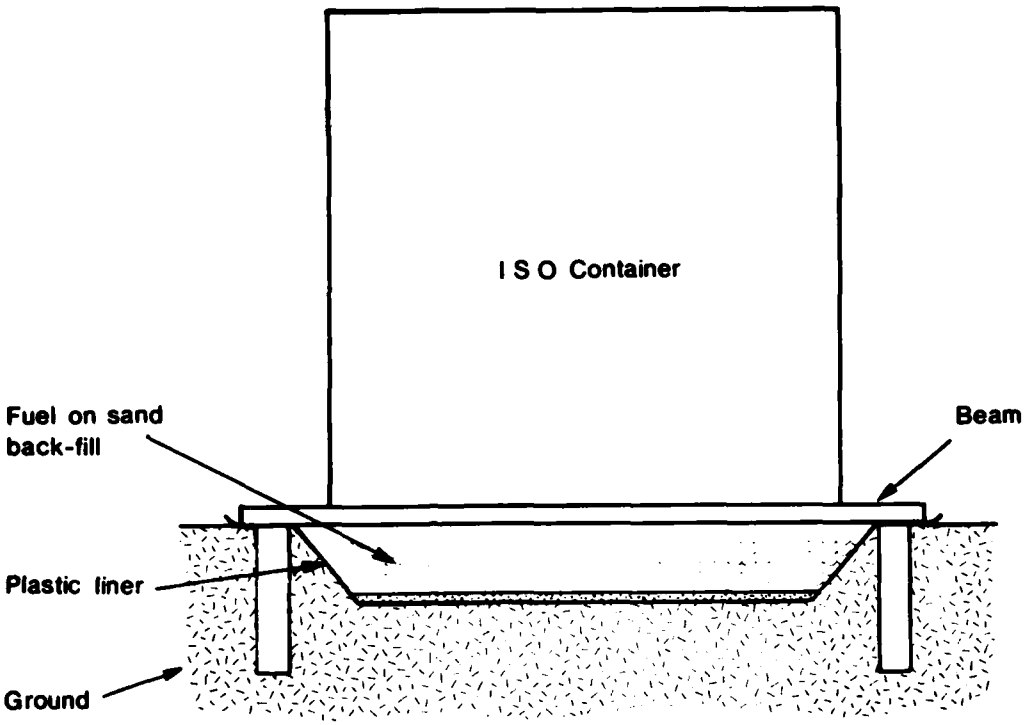


FIG. 12a - Schematic of the fire hearth and container (Trial 6D/77).

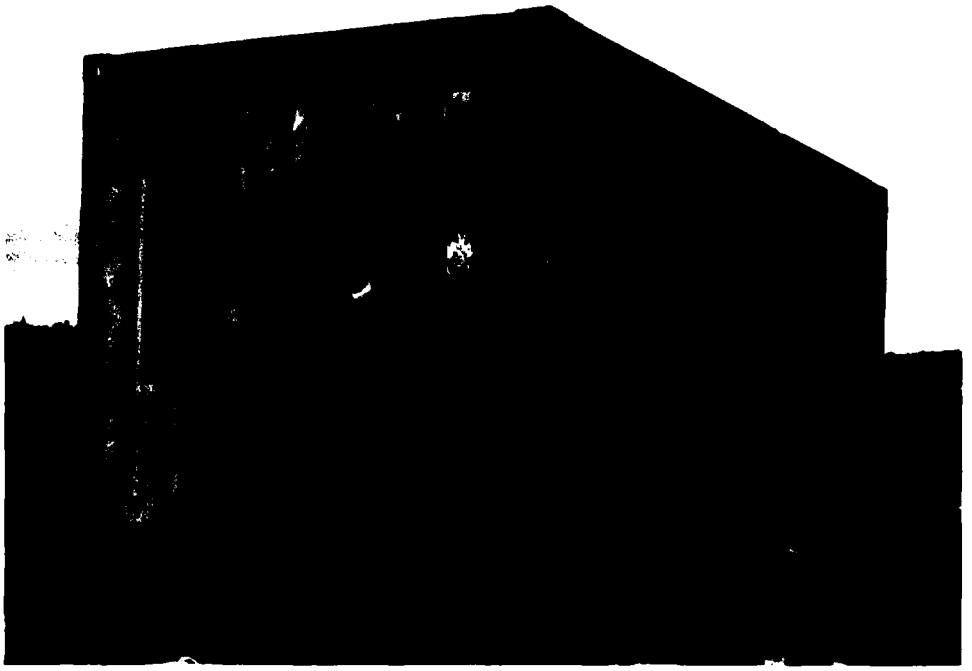


FIG. 12b - Photograph of the container supported above the hearth. (Trial 6D/77).

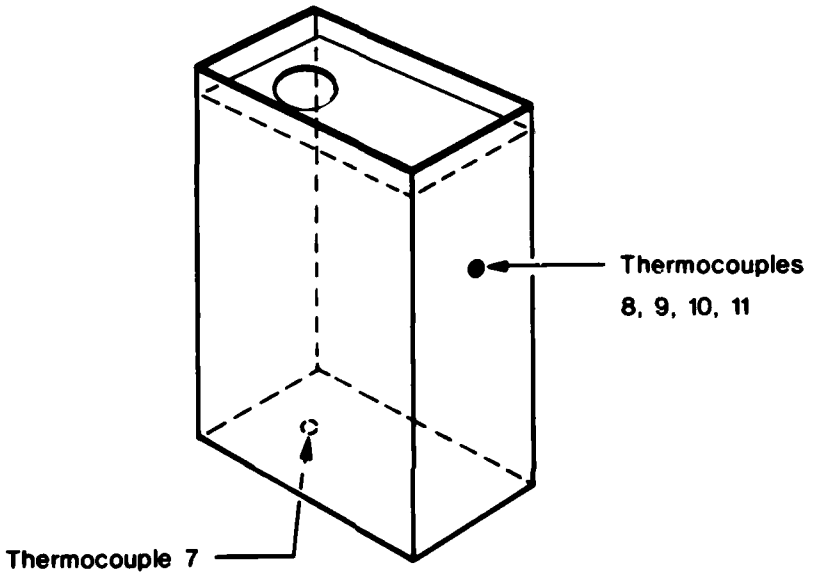


FIG. 13 - Schematic of thermocouple position for pallet/can configuration E/7, E/9, F/7, M/9, N/7 (Trial 6D/77).

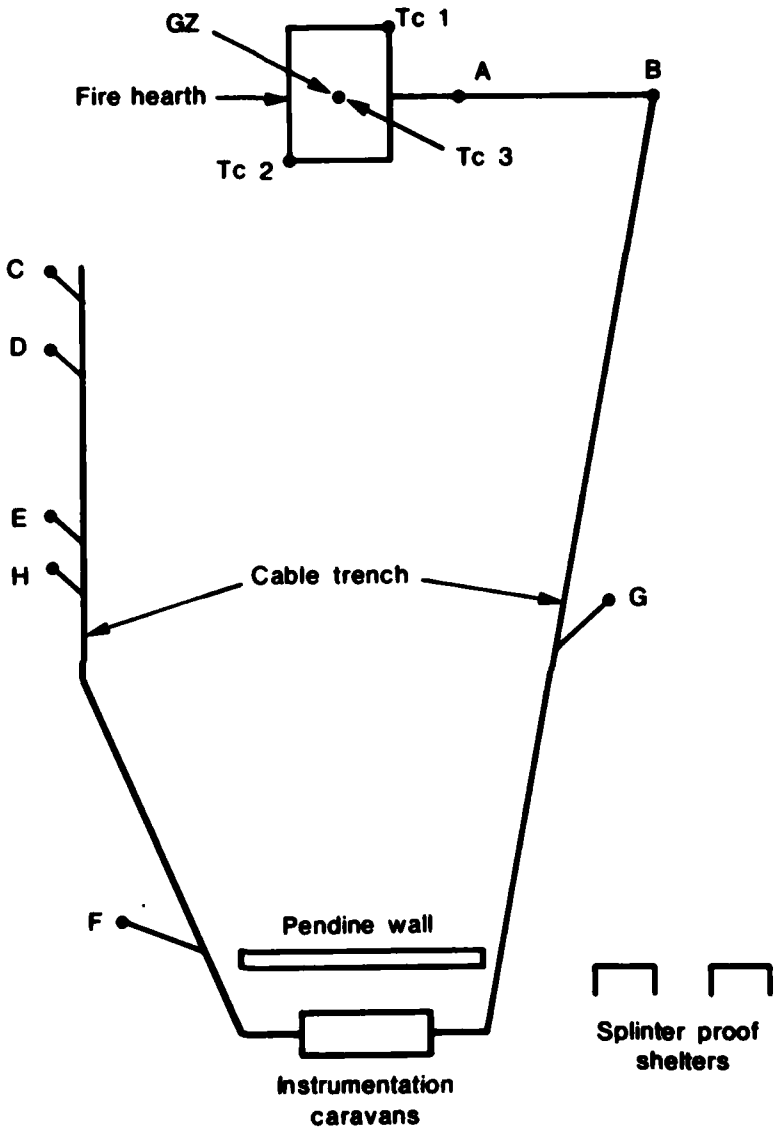


FIG. 14 - Instrumentation Layout (Trial 6D/77).

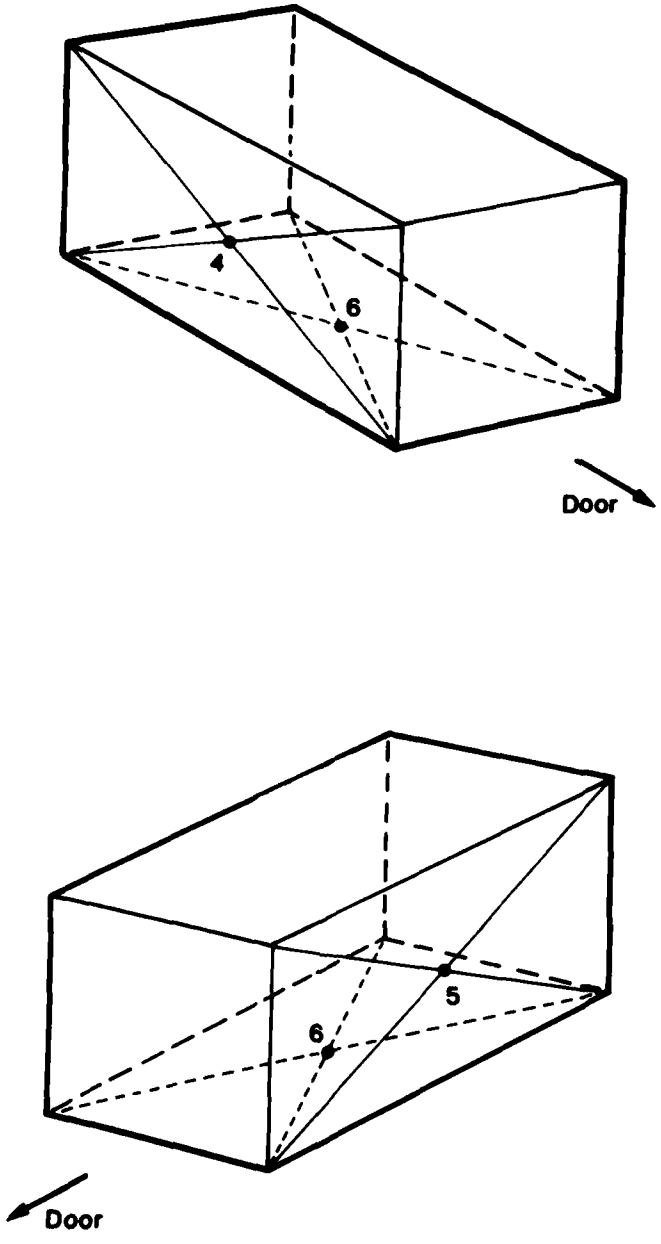


FIG. 15 - Schematic of thermocouple positions in ISO container (Trial 6D/77).

FIG. 16 - Photograph of the Kistler 701A gauges mounted on baffle plates.

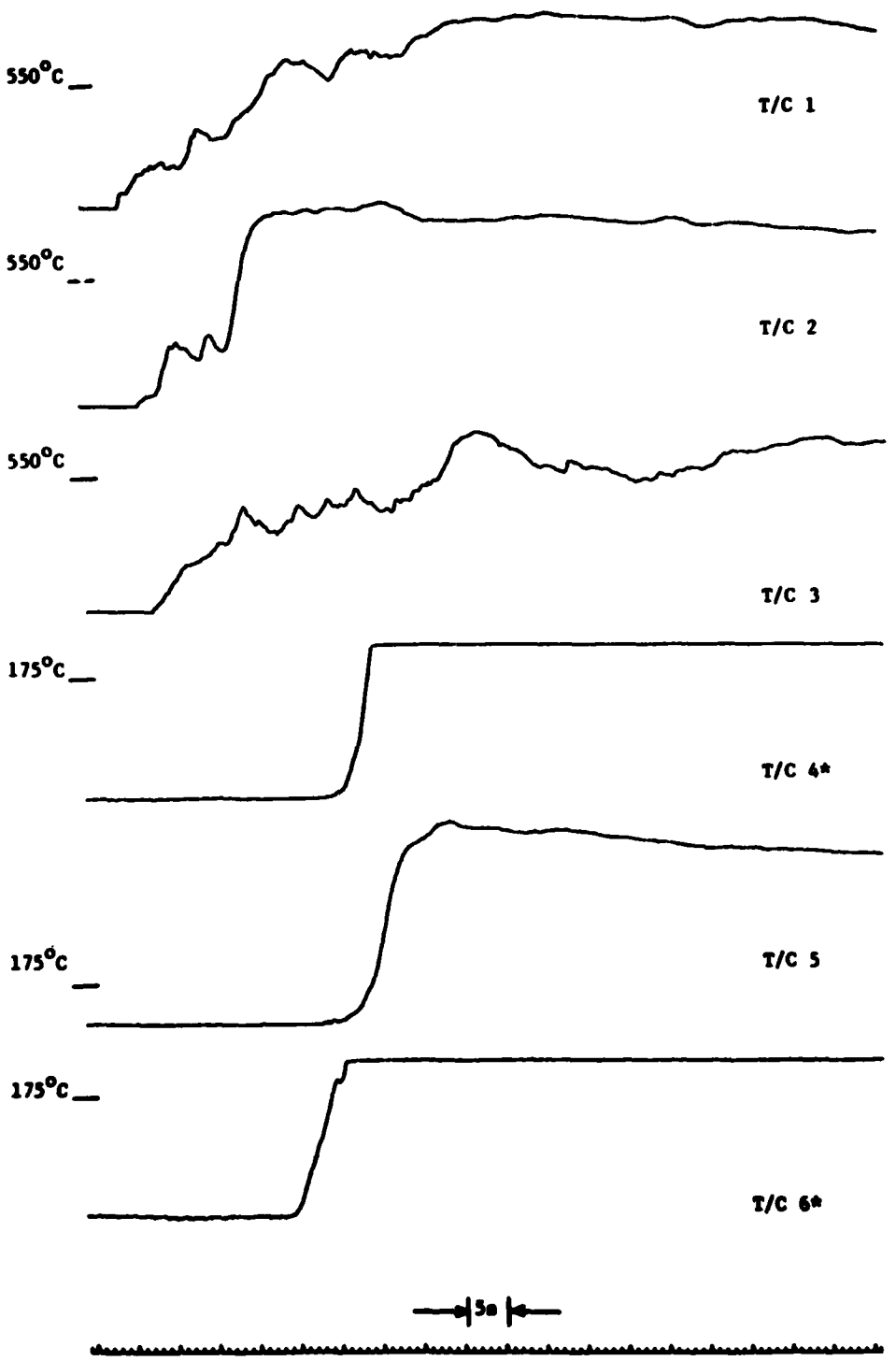


FIG. 17a - Temperature/time records of fire and container for Trial 6D/77.

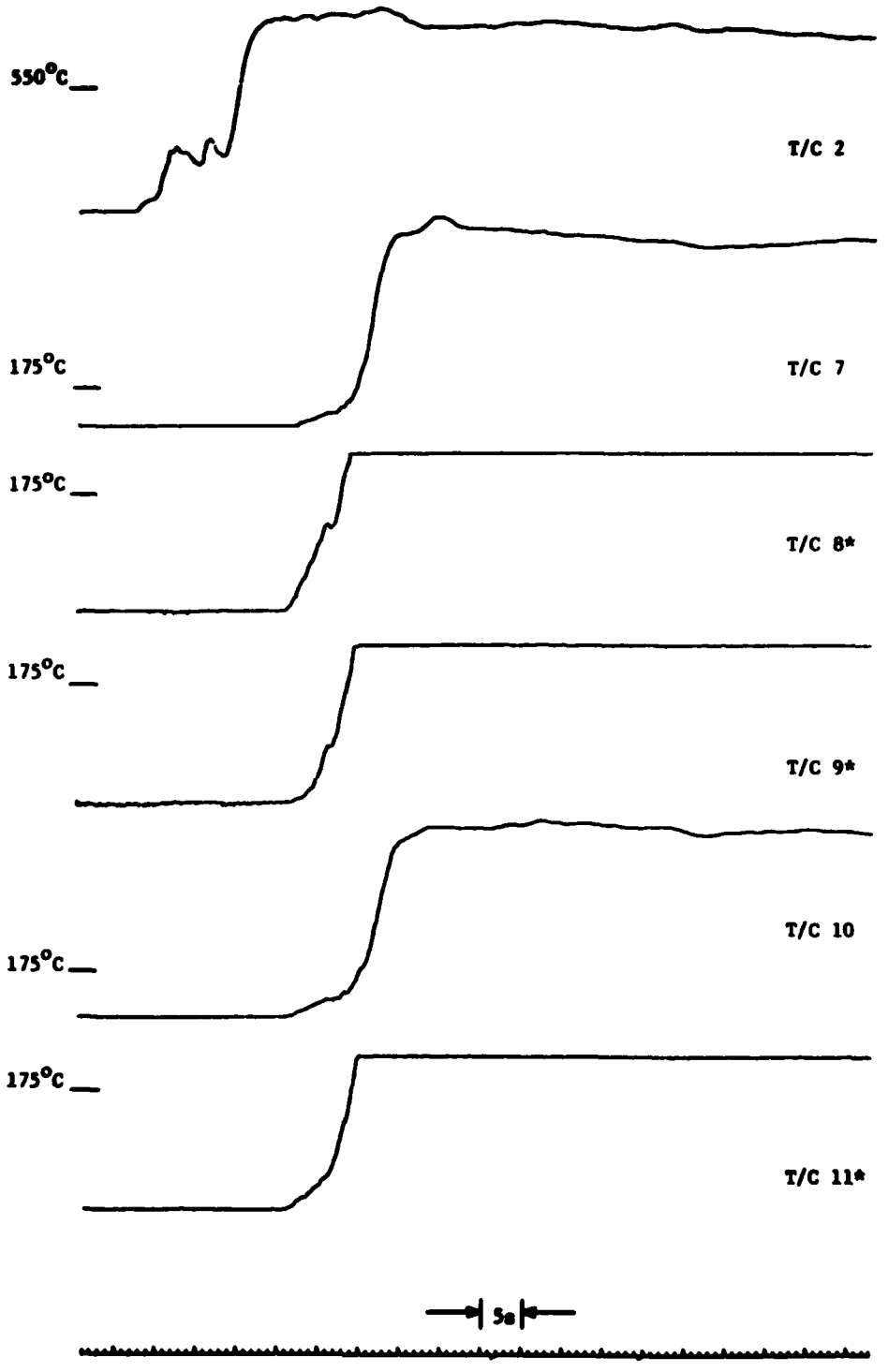


FIG. 17b - Temperature/time records of M2 cans in container for Trial 6D/77.

FIG. 18 - Photograph of the fuel fire and the burning propellant (Trial 6D/77).

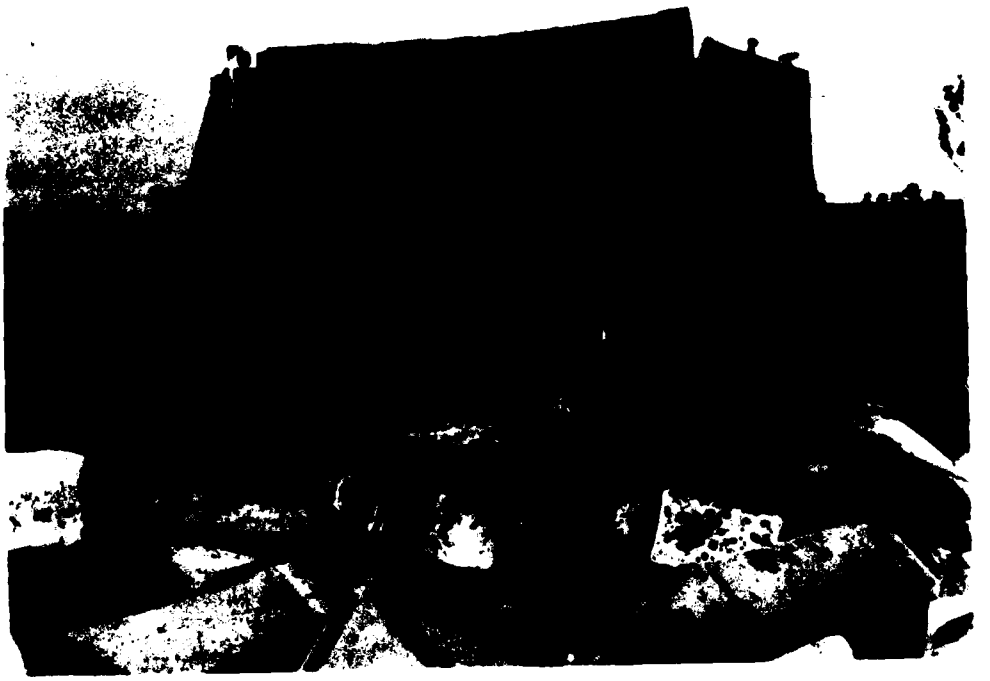


FIG. 19 - Photograph of the container and M2 cans after burning (Trial 6D/77).

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